AD-A079 697 NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY NSTL S--ETC F/G 8/10
INTERACTIVE DIGITAL SATELLITE IMAGE PROCESSING SYSTEM FOR OCEAN--ETC(U)
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6 # INTERACTIVE DIGITAL SATELLITE IMAGE PROCESSING SYSTEM FOR OCEANOGRAPHIC APPLICATIONS.

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11 April 1978

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NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
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ABSTRACT

The NORDA oceanographic satellite remote sensing program will emphasize data exploitation as opposed to data collection. This emphasis is because the collection technology has already far outstripped our ability to utilize the data for oceanographic purposes. The satellite data system described herein is an essential component for development and demonstration of processing, analysis, and interpretation methodology. The NORDA system includes a near real-time capability to receive GOES and limited VHRR data for screening purposes.

The system is considered baseline and several peripherals should be added in the future. Should time on the system be available beyond NORDA use, it will be open for use, with necessary support, to visiting Navy-sponsored scientists.

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INTERACTIVE DIGITAL SATELLITE IMAGE PROCESSING SYSTEM FOR OCEANOGRAPHIC APPLICATIONS

I. INTRODUCTION

Remote sensing from aircraft and satellites is routinely applied in many environmental disciplines such as geology, forestry, agriculture, and meteorology. Historically, most of the advances in data collection, processing, and analysis equipment and methods have been first envisioned and funded by the intelligence and mapping communities and then applied by others. No doubt this was due to the absolute military need for current information about inaccessible areas of the earth. In recent years, a national effort to explore in space has coupled with these other interests to further support development of remote sensing technology.

Generally speaking, remote sensing does not provide the absolute hard data obtained by in-situ sensing. In an effort to obtain increased objectivity in remote sensing programs, most workers incorporate a degree of ground truth for control of the remotely sensed data. This is similar to the procedure of field survey for provision of horizontal and vertical control in producing topographic maps from aerial photography.

The advantages of remote sensing are ease and cost-effectiveness of covering large areas rapidly. From satellites we obtain synoptic views on a global scale, in various portions of the electromagnetic spectrum, and on an hourly basis. Necessary economic tradeoffs have resulted in relatively coarse spatial resolution systems (in the range of one to a few km) associated with the environmental satellites. These resolution and coverage periodicity specifications while poor for certain objectives, are well suited for meteorology which was assumedly the driving discipline.

More recently, oceanographers are attempting to utilize satellite imagery for a wide variety of applications in the deep, coastal, and polar environments. The vast, inaccessible and dynamic scope of the oceanic regime (coupled with the large size of many marine features of interest) is a setting apparently well-suited for exploitation by environmental satellites. This fact has been recognized by several national and international organizations and has resulted in the recent launching of several new systems whose characteristics including resolution, spectral coverage, orbit, and periodicity have been designed around oceanographic objectives. These programs anticipate that major cost benefits and scientific advances in the oceanic environment will be realized as new information and techniques are presented. The key to providing this information from the maze of satellite remotely sensed data will be the development of capabilities to process and analyze the data from an oceanographic viewpoint. To realistically address this problem, a computer-based processing and analysis system with provision for easy human interaction must be utilized.

At NORDA, and other laboratories, this line of reasoning has led to a program which emphasizes data exploitation via digital interactive means. This technical note describes NORDA's Interactive Digital Satellite Image Processing System (IDSIPS), the analysis system which supports this program, and some of the initial oceanographic projects which will utilize this capability.

II. SYSTEM DESCRIPTION

The IDSIPS consists of the hardware components shown in Figure 1. The system, built by the International Imaging Systems (I^2S) Division of Stanford Technology Corp., is basically their off-the-shelf system 101 with some custom modifications to meet NORDA requirements. The CPU is a Hewlett-Packard mini-computer (HP 3000 Series II) with 256K bytes of memory. Computer peripherals include three 9-track tape drives (800 or 1600 bpi), two disc drives of 50 and 200 M bytes, line printer, operators terminal and programmers interactive display terminal.

The computer system peripherals and the I^2S Model 70 analyst console are shown in Figure 2. The analyst's console consists of a 19-inch, high-resolution color monitor which displays a 512 x 512 pixel image. The display refresh consists of three channels of 8-bit Random Access Memory for image data and four bit-planes for graphics overlays. A feedback buffer combined with an Arithmetic Logic Unit in the Model 70 permits many analysis functions to be performed in the display electronics at video rates without burdening the CPU.

Analyst interaction is by means of a display terminal and a trackball controlled cursor. The user may enter graphic information such as bathymetric charts via the camera input system. Working quality black and white image hardcopy is available to the analyst in 18 seconds.

The IDSIPS facility is connected by direct phone line to the NOAA/NESS Satellite Field Services Station in Washington, D. C. for the near real-time receiving of GOES and selected VHRR data. Phone line transmissions are digitized upon reception and input to the computer system for storage, display, or analysis.

The IDSIPS occupies a 500 sq. ft. area adjacent to offices of NORDA remote sensing personnel. The facility is divided into a computer room and analyst room as shown in Figure 3. Working space is provided for visiting investigators.

A complete repertoire of image analysis software is provided on the IDSIPS. The computer manufacturer has supplied CPU operating and support software including compilers, file management and editing, debugging, and scientific subroutine libraries. However, unique image processing capabilities result from additional applications software. Applications software consists of over one hundred analyst callable functions to perform radiometric or geometric corrections to an image, accomplish pattern classification, perform statistical analysis, transform and filter image data, and enhance image displays. Uniform command language syntax and a user prompting are employed to facilitate system usage without extensive training.

III. OCEAN SCIENCE APPLICATIONS

The system described above will play an important role toward satisfying the goal of developing and demonstrating the effective use of satellite remote sensors in oceanographic research and in prediction for naval operations. Objectives to be addressed accomplishing this goal can be grouped as follows:

- Thermohaline structure to depths of acoustic detection significance
- Sea surface directional spectra/surface winds
- Arctic ice conditions

- Coastal conditions of inshore warfare significance.

If satellite observations can provide the parameters shown on Table 1, then through modeling developments significant advances should be made in oceanographic predictions. Satellite coverage is expected to provide modelers the vital missing link between the paucity of recent simultaneous in-situ measurements and historic environmental data sets (which may be of very limited use in specific applications). The Navy has many unique requirements for highly detailed environmental information over wide ocean expanses in a 12- to 24-hour time frame. This challenge must rely heavily on a combination of in-situ, historic, and satellite data welded together by modeling intuition. To date, theoretical examinations and limited field experimentation have provided indications that environmental satellite sensing will be successful in satisfying many oceanographic objectives.

At NORDA, several projects have been initiated which will use the IDSIPS in the oceanographic analysis. Some of the system capabilities to be utilized in the below described efforts are interactive level slicing, contrast stretching, sensor calibration, atmospheric correction, contouring, mensuration, registration of earth coordinates, unsupervised pattern classification and pseudocolor display. Brief descriptions of these efforts follow:

1. Philippine Sea - The primary objective of this project is to provide information regarding ambient noise and other impacts due to environmental causes, e.g., sea state, fronts, eddies, and surface winds. In the conduct of this work, data from various platforms as listed in Table 2 will be utilized. An extensive amount of surface and subsurface environmental data, as well as measurements from low-flying aircraft, will be available as ground truth control for the satellite and high altitude data collection aircraft.

2. Pacific Coast Upwelling - Chlorophyll, sediment, and other constituents can give water masses characteristic colors which permit delineation of many of the same features that are observed in thermal images. Water color may yield clues about the origin and dynamics of upwellings, fronts and eddies which would not be apparent from thermal data alone. Thus, the objective of this experiment is to demonstrate that remotely sensed ocean spectral reflectance (water color) is a useful interpretive aid in the study of the dynamic features of the ocean.

Data from LANDSAT, NOAA, and GOES satellites, plus Ocean Color Scanner data from the NASA U-2 aircraft, has been collected over the test area for the month of September, 1977. The experiment area is bounded by 37° and 43° N, 124° W, and the California coastline. This time and location corresponds to SURVOPS 1977 activities by the NAVOCEANO Sea Scan aircraft whose AXBT and ART data will provide ground truth for the satellite analysis. Data analysis will be performed on NORDA's Interactive Digital Satellite Image Processing System. Comparison of multispectral analysis with the analysis of thermal imagery such as the DMSP data shown in Figure 4 will achieve the objective of the experiment.

3. Grand Banks - The objective of this experiment is to determine if data from satellite and aircraft synthetic aperture radars can be used to derive destinctive sea-state patterns that are indicative of the surface position of ocean current boundaries. The experiment will take place in the region located between 42° and 52° W and 38° and 47° N. Figure 5 is a NOAA satellite thermal image showing the pronounced thermal structure typical of this area where the Gulf Stream and Labrador waters interact. Satellite data will be

collected at Toronto, Greenbelt, St. Johns, and Prince Albert. GOES, NOAA and TIROS-N real-time data will be collected in Toronto and flown daily to St. Johns for operational application. The USNS LYNCH plus three remote sensing aircraft will be utilized in support of the joint US-Canadian experiment. The experiment will be conducted in two phases. The first phase, called Baseline, will take place during two weeks in late June 1978. This phase will utilize data from presently available sensors. New look, in May of 1979, will repeat Baseline plus evaluate new sensors aboard SEASAT and other satellites launched since Baseline.

4. South Pacific Shoals - This is a pilot effort to investigate the utilization of multispectral visible and near-infrared satellite data to detect and delineate the position of shoals which extend to within 25 to 50 feet of the ocean surface. Initially LANDSAT data will be used and, if successful, future efforts anticipate using the five-channel scanner (CZCS) aboard NIMBUS G when it is launched in late 1978.

5. Techniques Development - In addition to the types of oceanographic applications projects represented by the above descriptions, NORDA is engaged in remote sensing techniques development. Such areas as algorithm development, error analysis studies, image enhancement techniques, and multisatellite methodology will be supported by the interactive computer facility.

IV. NORDA OPERATING FRAMEWORK

NORDA plans to make the digital satellite data system available to other Navy-sponsored programs on a non-interference basis. Current plans are to operate the system on a single-shift basis during the normal work week. Should it be necessary, a second shift can be added to accommodate demands. Generally, a block of time will be scheduled for an investigator's uninterrupted use. On occasion, when a researcher requires near real-time information to assist in guiding at-sea data collection operations, the IDSIPS will be utilized for receiving, displaying, and quick-look screening and analysis purposes on a priority basis. For further information contact the authors at NORDA, (601) 688-4864 or AV-485-4864.

TABLE 1

NEEDED PARAMETERS FOR THERMOHALINE MODELS*

PARAMETER	ACCURACY	RANGE	HORIZ. RESOL.	FREQUENCY	AREA SIZE
Rel. SST	.25°C 0.5 °C	10°C 35°C	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Abs. Wind Stress Vect.	0.2 Dynes/cm^2 0.25 Dynes/cm^2	0–20 Dynes/cm^2 0–20 Dynes/cm^2	5 km 30 km	3 hr/15° 12 hr/45°	200 x 200 km Ocean Basin
Ice Cover	% Cover % Cover	10% 10%	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Rel. Surface Topo.	3 cm 5 cm	1 Meter 2 Meters	5 km 30 km	24 hr 72 hr	200 x 200 km Ocean Basin
Net Heat Flux	10 cal/cm^2/day(?) 20 cal/cm^2/day(?)	5–100 5–100	5 km 30 km	12 hr 24 hr	200 x 200 km Ocean Basin
Abs. SST	0.5°C 0.5°C	0–35°C 0–35°C	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Insolation	2 cal/cm^2/day 10 cal/cm^2/day	5–500 5–500	5 km 30 km	12 hr 24 hr	200 x 200 km Ocean Basin
Turbidity	0.1–10 mg/l .005 mg/l	0.2–50 mg/l .01–0.7 mg/l	5 km 30 km	3 hr 12 hr	Coastal Open Ocean
Abs. Air Temp.	0.5°C 1.0°C	-50°C to 40°C -50°C to 40°C	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Barom. Pressure	5 Millibar 5 Millibar	960–1020 mb 960–1020 mb	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin

TABLE 1

NEEDED PARAMETERS FOR THERMOHALINE MODELS (CONT.)

PARAMETER	ACCURACY	RANGE	HORIZ. RESOL.	FREQUENCY	AREA SIZE
Rain	1 mm/hr 1 mm/hr	1-100 mm/hr 1-100 mm/hr	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Rel. Humidity	± 5% ± 5%	0-100 0-100	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Currents	cm/sec (10%) cm/sec (20%)	4-400 4-400	5 km 30 km	3 hr/15° 12 hr/45°	200 x 200 km Ocean Basin
Sea State Height	50 cm 50 cm	0-15 meters 0-15 meters	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin
Salinity	0.05 ppt 0.1 ppt	0-40 ppt 0-40 ppt	5 km 30 km	3 hr 12 hr	200 x 200 km Ocean Basin

(*S. Piacsek, et al)

TABLE 2

PHILIPPINE SEA DATA ENVIRONMENTAL APPLICATIONS

MODE	DATA	PARAMETER	APPLICATION	SOURCE
<u>SATELLITE</u>				
LANDSAT-II	.5-1.1 μm Photography and computer compatible tapes (CCT)	Water turbidity/color	Currents, boundaries	NASA
DMSP-5D	Visual and thermal photography and CCTs	Reflectance radiom temp. (SST)	Currents, fronts, eddies	DNOM
NOAA-5	Visual and thermal photography and CCTs	Reflectance radiom temp. (SST)	Currents, fronts, eddies	NESS
GEOS-3	Altimeter	Surface roughness Sat. altitude	Wave height (noise) Sea surf. topog. (currents, eddies)	NASA
NIMBUS	Infrared radiometer (11.5 μm and 6.7 μm)	SST, prec. moist.	Currents, fronts, etc.	NASA

TABLE 2

PHILIPPINE SEA DATA ENVIRONMENTAL APPLICATIONS (CONT.)

MODE	DATA	PARAMETER	APPLICATION	SOURCE
Aircraft	AXBT High+low altitude B & W photography Laser profile tapes Radiometric temperatures	Thermal profile reflectance etc. Micro-altitude SST	Acoustics sea state (noise) Wave height (noise) currents, fronts	DoD
Surface	Temperature Salinity Sound speed Bathymetry Sub-bottom profile Geological and geophysical data Meteorology Sea surface observations			

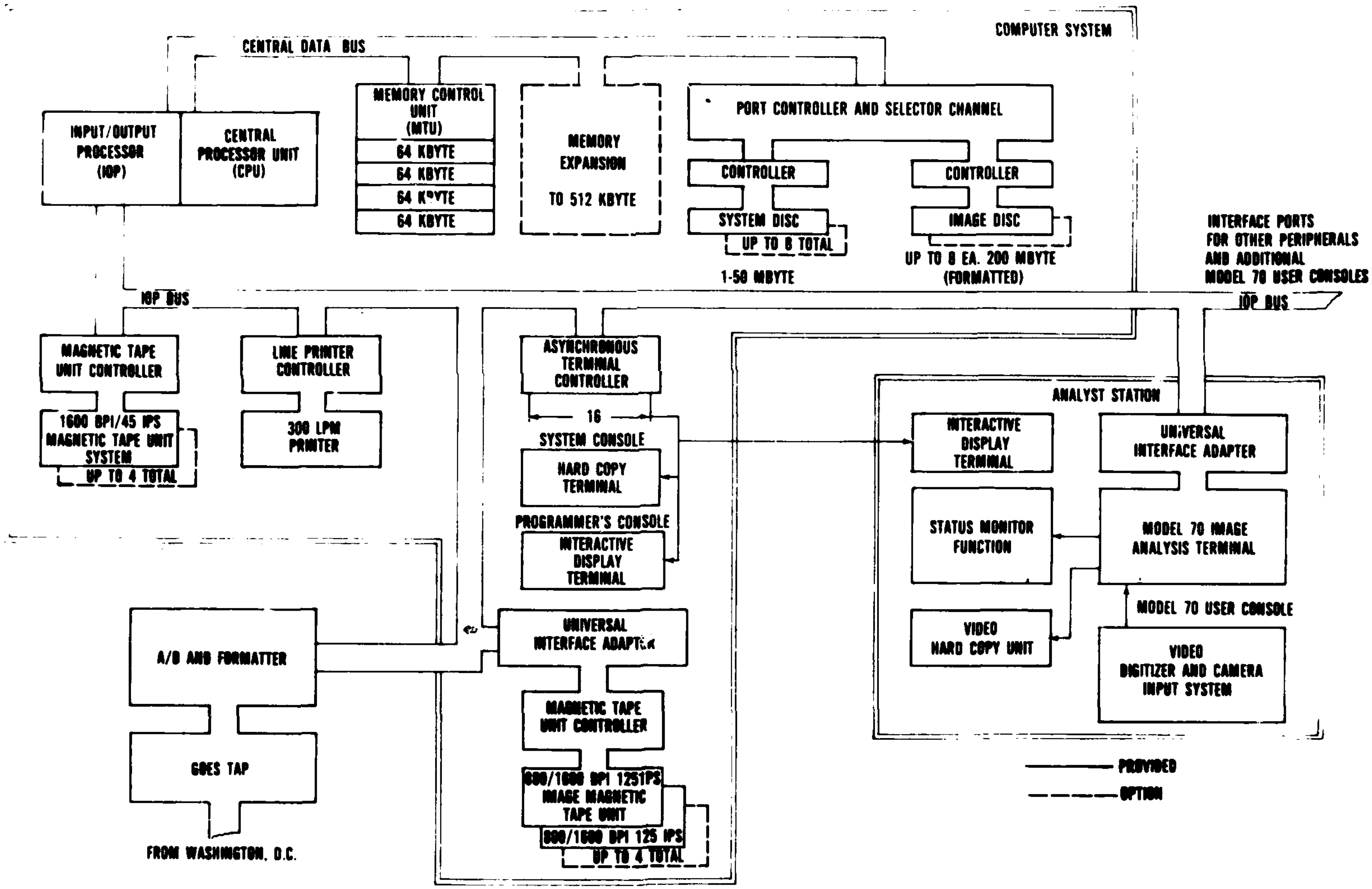

Figure 1. IDSIPS hardware configuration.

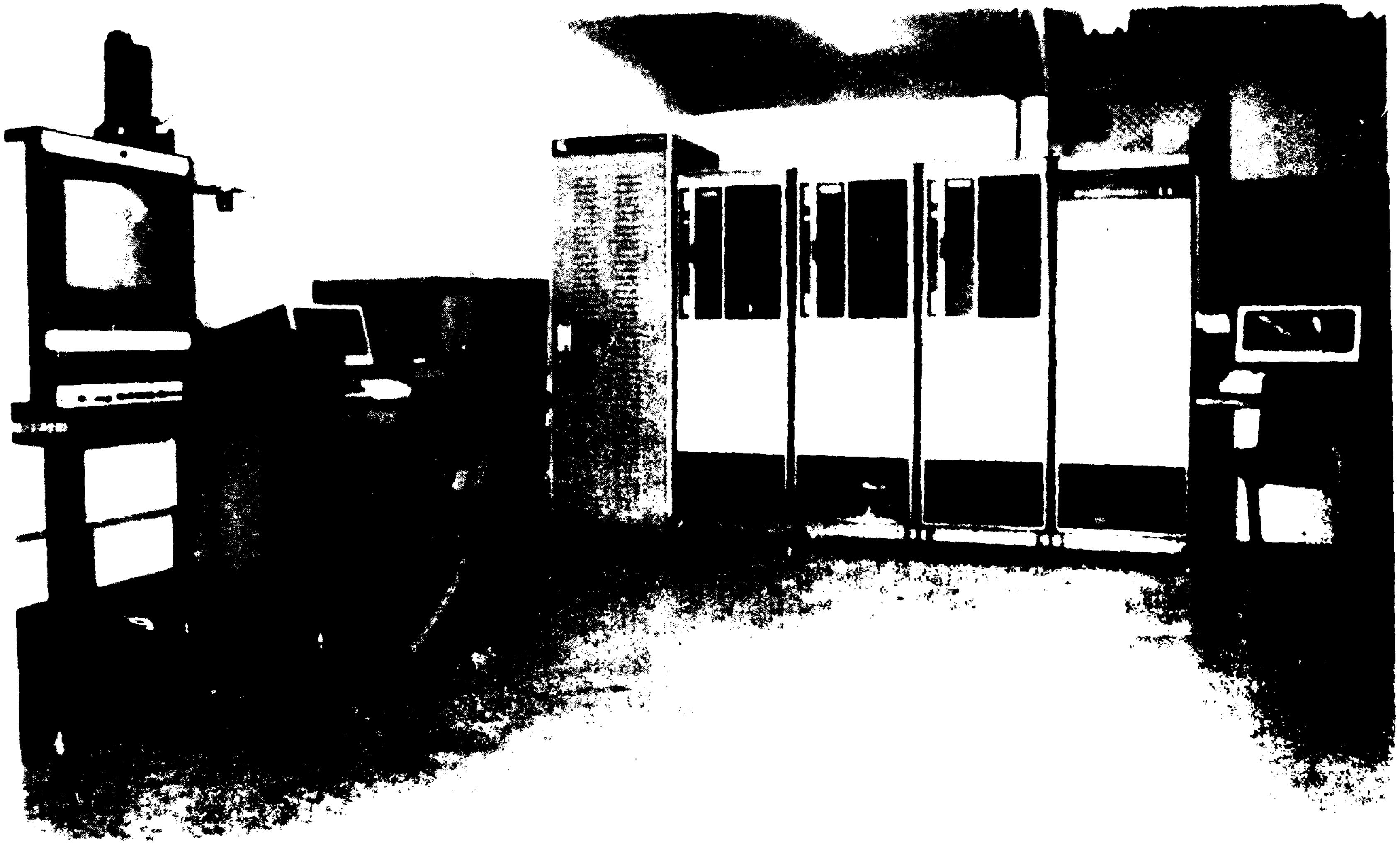

Figure 2. IDSIPS hardware system

COMPONENTS

NUMBER	ITEM
1	HP 3000 II, 208V, 3Ø
2	HP ISOLATED TAPE DRIVE
3	MOD. 70, 120V, 30A
4	DISC. DRIVE 9300, 208V, 3Ø
5	HP DISC. DRIVE, 120V, 5A
6, 7	PERTEC TAPE DRIVES (208V, 15A, EACH)
8	HP LINE PRINTER, 120V, 1A
9	SYSTEM CONSOLE, 120V, 1A
10	TAPE STORAGE
11	PROGRAM CONSOLE, 120V, 1A
12	ANALYST CONSOLE, 120V, 1A
13	ANALYST DISPLAY, 120V, 3A
14	VIDEO INPUT SYSTEM
15	VIDEO HARD COPY, 120V, 1.5A
16	ISOLATION TRANSFORMER 15KVA, 208/208V, 3Ø, 4 WIRE
17	TABLES NONISOLATED
18	MAP CASE
19	CAMERA
20	FILE CABINET
21	ISOLATED POWER PANEL PR41

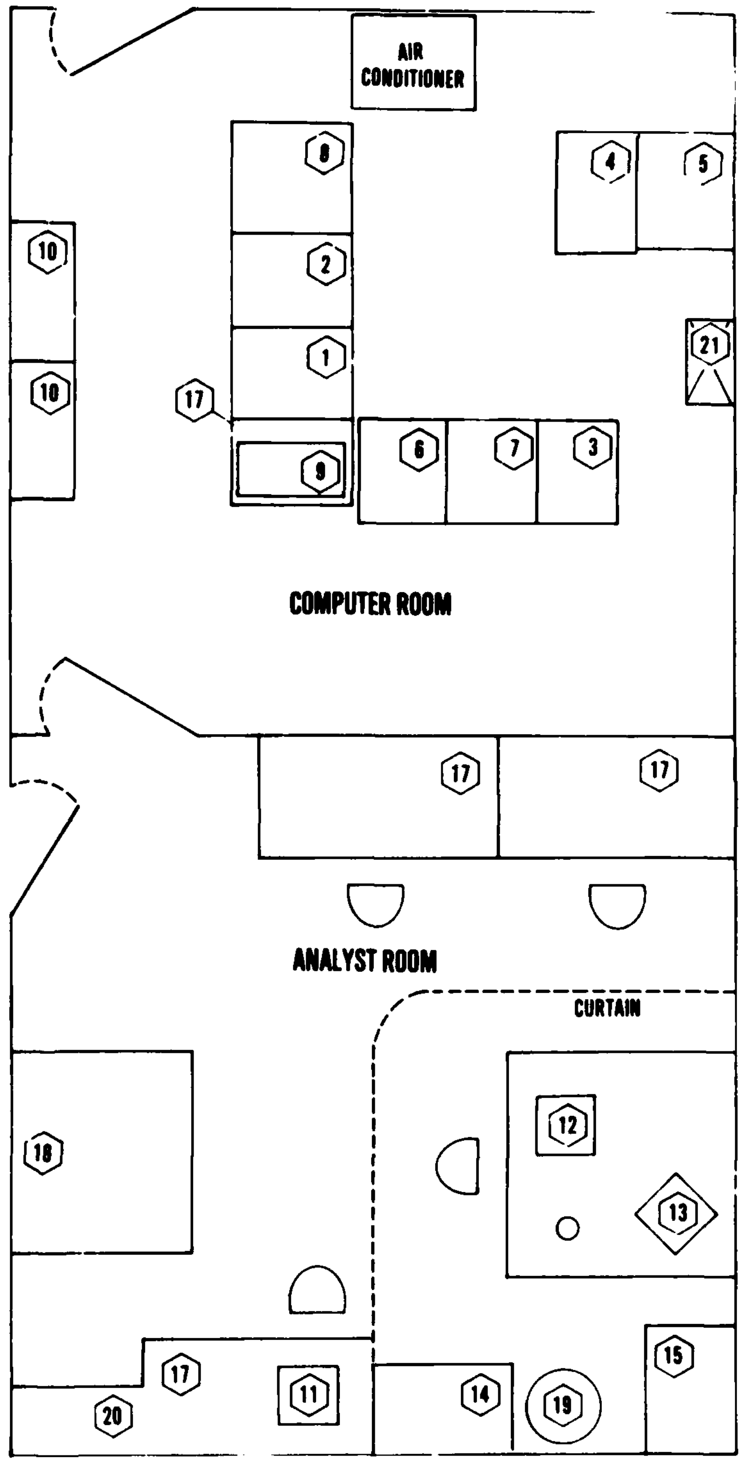

Figure 3. IDSIPS floor plan and list of components

Figure 4. Pacific coast updwelling test area showing sea surface thermal patterns (DMSP imagery)

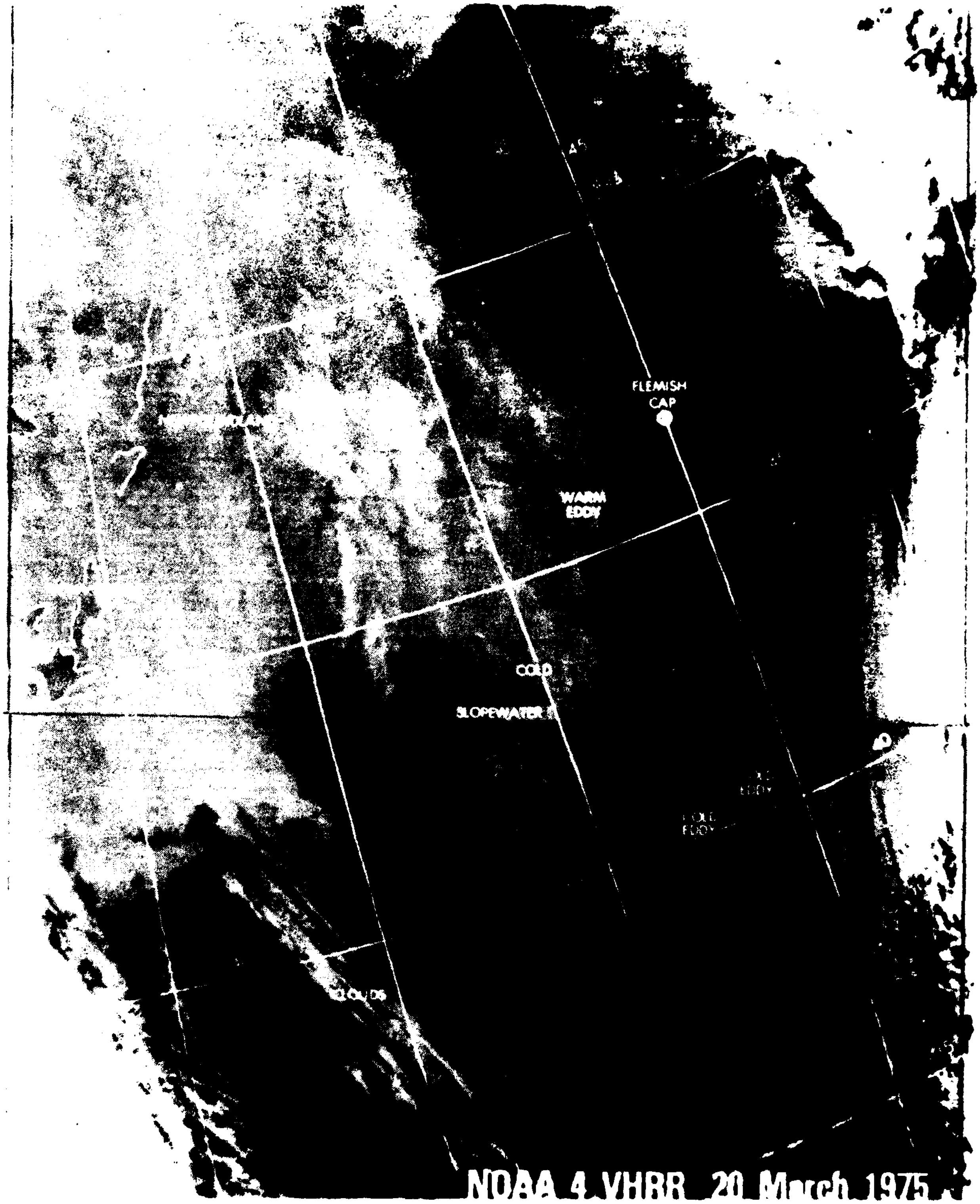

Figure 5. Grand Banks test area showing sea surface temperature patterns indicative of eddy formation

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Interactive Digital Satellite Image Processing System for Oceanographic Applications		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER NORDA Technical Note
7. AUTHOR(s) Albert E. Pressman and Ronald J. Holyer		8. CONTRACT OR GRANT NUMBER(s) None
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Research and Development Activity NSTL Station, MS 39529		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Ocean Research and Development Activity NSTL Station, MS 39529		12. REPORT DATE April 1978
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Ocean Research and Development Activity NSTL Station, MS 39529		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Satellites
Remote Sensing
Oceanography
Interactive Digital Processing
Environmental Sensing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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